

Ocean Coupling to Topographically-Enhanced Atmospheric Flow

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LONG-TERM GOALS

The goal of this project is to understand and predict oceanic and atmospheric processes in coastal areas where winds are topographically steered and strengthened.

OBJECTIVES

The proposed work aims to probe details of the interaction of mountainous island terrain with synoptic and intra-seasonal disturbances, and the associated ocean response and feedback. The research questions include:

- How do intra-seasonal and synoptic disturbances combine to generate spatial/temporal variability of the ocean and atmosphere on small time and space (e.g., operational) scales?
- How do terrain effects influence local precipitation and wind patterns during atmospheric episodes?
- How do warm wake waters surrounding islands impact the atmosphere during synoptic and intra-seasonal events? What is the evolution of atmospheric and oceanic boundary layers over the course of atmospheric passages, and what role do wind orientation and terrain play?

APPROACH

To accomplish these objectives we employ high-resolution (~1-3 km) two-way coupled ocean/atmosphere modeling to predict, interpret and improve the simulated boundary layer properties. The studies mine the rich datasets of observational programs including land-based meteorological data, satellite, moored and underway observations to form a more complete picture of circulation characteristics in the ocean and atmosphere in complex coastal mountainous regions. The project is a close collaboration with NRL partners on the modeling side (including James Doyle, Paul May and Maria Flatau) and field team participants (including Arnold Gordon of Lamont-Doherty Earth Observatory, Janet Sprintall of Scripps, Craig Lee of University of Washington, and Cesar Villanoy of University of the Philippines).

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WORK COMPLETED

During December 2007-February 2008 the Philippines experienced the greatest rainfall in 40 winters. We used a combination of observations along with 3 km resolution two-way coupled COAMPS^{®1} (May et al., 2011) to examine this anomalous season with a particular focus on MJO and La Nina influences.

The Philippines national weather service (PAGASA) supplied 3-hourly meteorological station data at ~50 sites distributed throughout the Philippine islands. The dataset covers the 5-month time period 1 November 2007 – 31 March 2008. These data have been compared with coupled COAMPS^{®1} simulations, shipboard measurements, and TRMM precipitation radar measurements from the same time period, and also with climatology.

(¹ COAMPS[®] and COAMPS-OS[®] are registered trademarks of the Naval Research Laboratory.)

RESULTS

As expected from climatology, rainfall was greatest on the eastern side of the Philippines archipelago (Akasaka et al., 2007). Wintertime totals for 2007-2008 were extreme and exceeded 4000 mm in some locations, a strong contrast with surrounding years (Figure 1). Discrete precipitation events delivered the bulk of the rain to the region and they corresponded with time periods of enhanced MJO activity (Figure 2). The 3-km COAMPS produced precipitation in the mountainous areas of the Philippines that drained into the coastal ocean, producing freshwater lenses (Pullen et al., 2011). Elevated rainfall from La Nina along with the event-based increases from MJO combined to deliver the wettest winter in 40 years to the region. The coupled model captured the MJO-influenced precipitation signal. In addition, the model represented the spatial pattern of highest rainfall in the mountains and on the eastern edge of the archipelago that is a ubiquitous feature of the area (Figure 3). The latter was partially measured by TRMM, but the former was missed due to measurement challenges in complex terrain (Iguchi et al., 2000).

Manuscript to be submitted to JGR-Oceans special issue on Western Pacific Ocean Circulation and Climate: “Extreme winter rainfall patterns in the Philippines,” J. Pullen, A. Gordon, M. Flatau, J. Doyle, and C. Villanoy.

IMPACT/APPLICATIONS

The ability to predict the evolution of topographically-enhanced events/features that occur on multiple timescales (synoptic, intra-seasonal and longer) has been demonstrated here. Thus this effort is directly applies to enhancing spatial/temporal prediction of coupled coastal processes worldwide.

Furthermore, insight into circulation patterns in coastal areas subject to topographically-enhanced processes are translatable to other regions of interest to the Navy. Wind and precipitation events may influence Navy operations near island coasts and important ports in the western Pacific, as well as worldwide.

RELATED PROJECTS

This work is related to NRL-Monterey 6.1 projects within PE 0601153N that include studies of air-ocean coupling, boundary layer studies, and topographic flows and 6.2 projects within PE 0602435N that focus on the development of the atmospheric and coupled components of COAMPS. This work also draws on efforts conducted within the ONR PhilEx DRI, ONR OKMC DRI, and ONR DYNAMO DRI.

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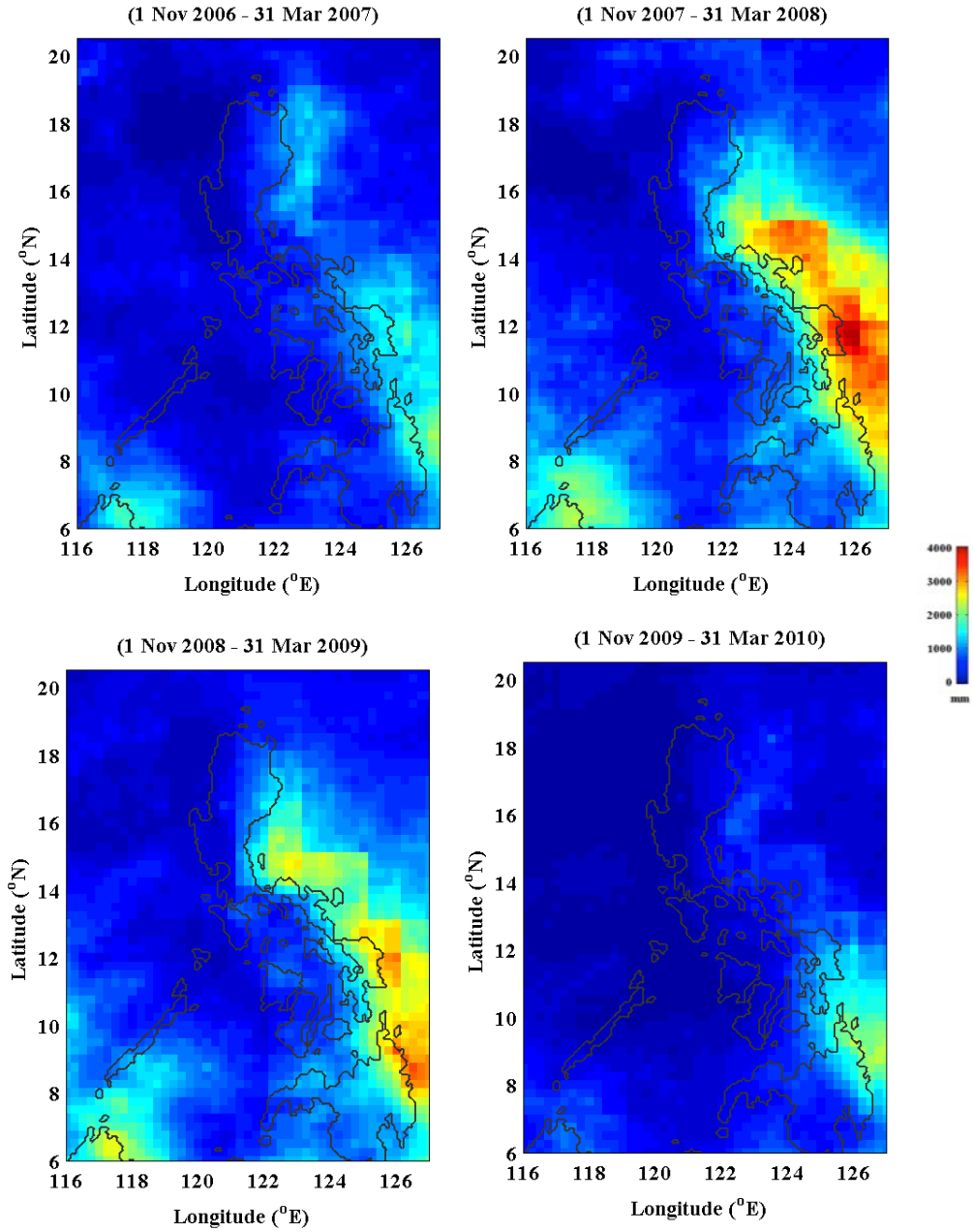


Figure 1: TRMM measurements of rainfall total (in mm) for 1 November – 31 March for four consecutive years. The anomalous period (1 Nov 2007 – 31 March 2008) is shown in the upper right.

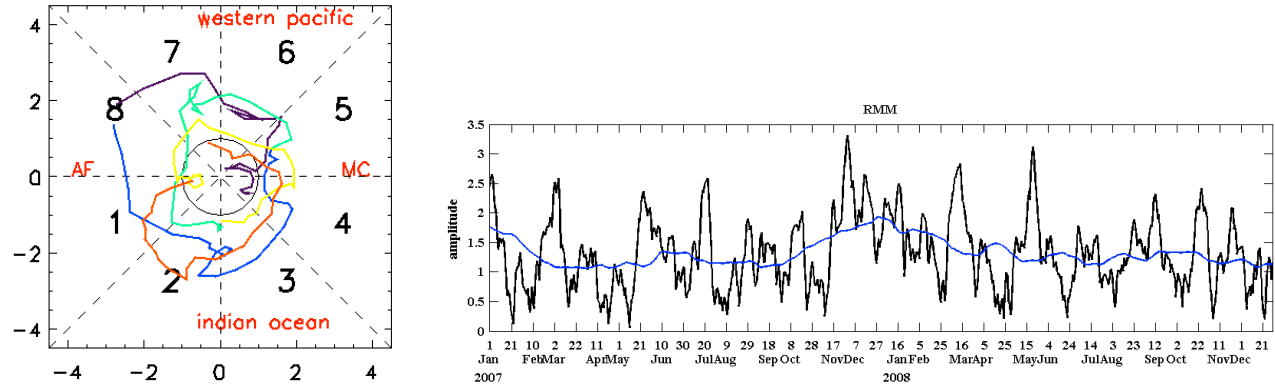


Figure 2: Wheeler-Hendon diagram for 11 November 2007 to 31 March 2008 showing the amplitude and phasing of MJO. The Maritime Continent (MC) is labeled. The dark purple=Nov 2007, blue=Dec 2007, green=Jan 2008, yellow=Feb 2008 and red=March 2008. The right plot is RMM amplitude in black, with the 90-day running mean in blue. Enhanced MJO activity is evident beginning in Nov 2007.

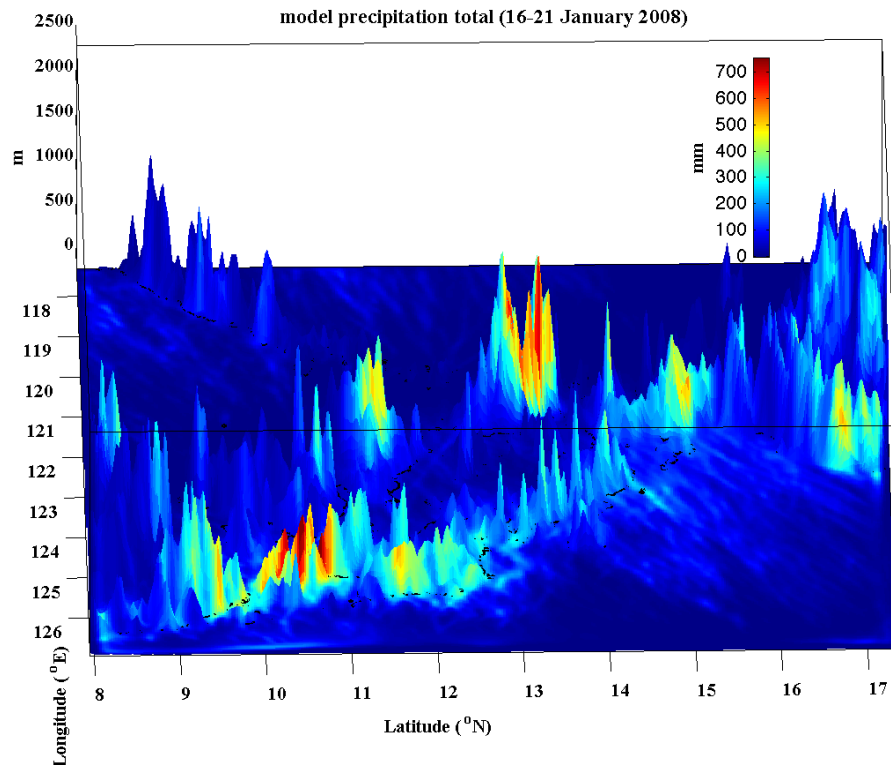


Figure 3: 3 km resolution coupled COAMPS precipitation total for 16-21 January 2008, during an MJO episode (also verified with a time -longitude plot of the TRMM precipitation in mm/day averaged between 6-19N, not shown). The figure shows the island of Mindoro in the center, with greatest rainfall in the mountains. (The orientation is from the east looking west.)